Elementary: Jurnal Ilmiah Pendidikan Dasar
Volume 12, Nomor 1, Tahun 2026, ISSN: 2579-9282
https://e-journal.metrouniv.ac.id/index.php/elementary

Development of GeoGebra-Based Mathematics Learning Media for Elementary School Students

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Received: 14/05/2026	Accepted : 26/06/2026
Revised : 02/06/2026	Published : 27/06/2026

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DOI: https://doi.org/10.32332/elementary/v12.i1.13628

Abstract

Mathematics learning on triangle material in elementary schools still faces various challenges because geometric concepts are often abstract, and the learning process remains insufficiently interactive. These conditions affect students' conceptual understanding and engagement during the learning process. Therefore, instructional media capable of presenting geometric concepts in a concrete and interactive manner are needed. This study aimed to develop GeoGebra-based

learning media on triangle topics using the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation). The novelty of this study lies in the integration of GeoGebra with a Deep Learning approach that emphasizes concept exploration, active student engagement, and the development of critical and creative thinking skills through the real-time manipulation of geometric objects objects. The research subjects consisted of 21 fifth-grade elementary school students. The validation process involved two media experts and two subject-matter experts. Data were collected through questionnaires, observations, and documentation, while data analysis employed descriptive percentage analysis. The findings revealed that the media expert validation score reached 88% and the material expert validation score reached 83%, both of which were categorized as highly valid. In addition, student responses reached 91%, indicating that the learning media were highly practical. These findings demonstrate that the developed learning media are feasible for supporting more interactive, visual, and meaningful mathematics learning on triangle material in elementary schools.
Keywords: GeoGebra; Geometri Learning; Interactive Media; Elementary Mathematics

A. Introduction

Mathematics plays an important role in elementary education because it develops students' logical, critical, and systematic thinking skills (Wang, 2025). One of the fundamental topics introduced at the elementary level is geometry, particularly the concept of triangles, as it involves understanding shapes, angles, and the relationships among the sides of plane figures, while serving as a foundation for learning more complex geometric concepts (Novita & Herman, 2021). However, geometry learning in elementary schools continues to face several challenges. Many students experience difficulties in understanding triangle concepts because instruction tends to be abstract, monotonous, and teacher-centered, with limited use of interactive learning media (Fauzi & Arisetyawan, 2020; T. Siregar 2025). As a result, students often become less active and less motivated, which ultimately affects their conceptual understanding and mathematics learning outcomes.

The advancement of educational technology has encouraged the integration of visual and interactive learning media to facilitate students' understanding of abstract concepts in a more concrete manner (Duma & Modjo, 2025) . This is consistent with the characteristics of elementary school students, who are generally in the concrete operational stage and therefore learn more effectively through visualization and direct learning experiences (Susanto et al., 2024). Consequently, technology-based learning media are considered effective in enhancing students' engagement, motivation, and conceptual understanding in mathematics learning (Jaafar et al., 2022)

GeoGebra has been widely recognized as an effective learning medium for geometry instruction because it presents concepts in a visual, dynamic, and interactive manner. Its use enables students to understand abstract geometric concepts by visualizing the relationships and properties of geometric figures more concretely (Ziatdinov & Valles, 2022). Furthermore, its interactive features support the development of students' spatial reasoning skills through direct exploration and manipulation of geometric objects (Prasetya et al., 2024) . In learning triangle concepts, GeoGebra allows students to explore the properties of triangles interactively, enabling changes in angles and side lengths to be observed in real time and thereby strengthening their conceptual understanding (Duma & Modjo, 2025).

Previous studies have also demonstrated that GeoGebra enhances students' motivation, engagement, and participation in mathematics learning. Students tend to become more focused and actively involved in lessons supported by GeoGebra-based activities (Salamah & Jufri, 2025). Moreover, collaborative learning integrated with GeoGebra promotes greater interaction and cooperation among students during classroom activities (Sugiarni et al., 2025). These findings are consistent with observations in elementary schools, where students often remain passive during mathematics lessons and experience difficulties in understanding geometric concepts, particularly triangles. Therefore, the implementation of interactive and exploratory learning media such as GeoGebra is considered essential for providing students with opportunities for independent exploration and more meaningful learning experiences..

GeoGebra-based learning media have demonstrated considerable effectiveness in improving students' conceptual understanding, geometry visualization skills, and overall mathematics learning (Anggraeni, 2021). In addition, the Deep Learning approach has been shown to improve elementary school students' literacy and numeracy skills by emphasizing active engagement, in-depth conceptual understanding, and the development of critical thinking skills (Latif et al., 2025). Several studies have further reported that implementing the Deep Learning approach has a moderate to very high impact on students' learning outcomes (Fatimah et al., 2026). Nevertheless, studies integrating GeoGebra media with the Deep Learning approach remain relatively limited. Research conducted by F. D. Siregar et al (2025) combined these two approaches; however, it focused on trigonometry instruction for vocational high school students, making the findings less applicable to elementary school learners. Similarly Fatimah et al (2026) implemented a Deep Learning approach supported by interactive media for elementary school students, but their study was limited to science education rather than mathematics. Meanwhile (Ikhsan et al., 2024) developed the Geo-Math application integrating GeoGebra into geometry instruction and reported that the media met the criteria of validity, practicality, and effectiveness in improving

students' spatial abilities. Likewise Yerizon et al (2022) developed GeoGebra-assisted Problem-Based Learning worksheets that effectively enhanced students' mathematical problem-solving skills, while found that integrating GeoGebra into project-based learning produced better mathematics learning outcomes than conventional project-based learning. Despite these promising findings, the development of GeoGebra-based learning media integrated with a Deep Learning approach specifically for elementary mathematics instruction on triangle topics remains underexplored. Therefore, this study was conducted to develop an innovative and interactive learning medium that aligns with the characteristics and learning needs of elementary school students.

Previous studies have consistently demonstrated the effectiveness of GeoGebra in supporting geometry learning through visual, dynamic, and interactive representations that improve students' conceptual understanding, spatial reasoning, and engagement. Likewise, the Deep Learning approach has contributed to enhancing elementary school students' critical thinking, literacy, and numeracy skills by promoting active participation and in-depth conceptual exploration. However, the integration of GeoGebra with the Deep Learning approach in elementary mathematics learning, particularly for triangle topics, has received limited attention. Existing studies have generally emphasized visualization and interactivity without integrating exploratory learning activities that foster deeper conceptual understanding. Therefore, this study addresses this gap by developing GeoGebra-based learning media integrated with a Deep Learning approach using the ADDIE model. The developed media combines dynamic visualization, real-time manipulation of geometric objects, and interactive exploratory activities designed to accommodate the characteristics of elementary school students. Accordingly, this study is expected to contribute to the development of more interactive and meaningful mathematics learning media that support the acquisition of 21st-century skills.

B. Research Methods

This study employed a Research and Development (R&D) approach. Research and Development is a systematic research approach involving the processes of design, development, and evaluation to create or improve products, services, or processes (Branch, 2009). This study employed the ADDIE development model, which consists of five stages: Analyze, Design, Development, Implementation, and Evaluation (Branch, 2009).

The Deep Learning approach served as the pedagogical foundation for developing the GeoGebra-based learning media on triangle concepts and was integrated throughout each stage of the ADDIE model. During the analysis stage, students' learning needs, characteristics, and difficulties in understanding abstract

triangle concepts were identified. The findings from this stage served as the basis for designing an interactive learning medium capable of providing concrete visualizations and promoting active student engagement. During the design stage, learning activities were structured according to the principles of Deep Learning, emphasizing concept exploration, problem-solving, discussion, and reflection. During the development stage, the GeoGebra-based learning media were equipped with interactive features that enabled students to explore and manipulate geometric objects directly, thereby fostering independent conceptual understanding. During the implementation stage, the developed media were used to facilitate concept exploration, collaborative discussion, and contextual problem-solving, with the teacher serving as a facilitator. Finally, during the evaluation stage, the quality of the learning media, student engagement, usability, and students' responses to the learning experience were evaluated. Therefore, integrating the Deep Learning approach into the development of the GeoGebra-based learning media not only enhanced the visualization of mathematical concepts but also promoted meaningful, reflective, and student-centered learning.

The research participants consisted of 21 fifth-grade elementary school students aged 10–11 years who had previously studied plane geometry, particularly triangle concepts. The study was conducted at SD Kanisius Demangan Baru 1, Sleman, Yogyakarta, Indonesia. Participants were selected using purposive sampling, whereby subjects were chosen based on the research objectives and the relevance of the learning materials. In addition, the product validation process involved two expert validators, comprising one media expert and one subject-matter expert, both of whom possessed expertise in educational technology and elementary mathematics education.

Data were collected through observation, questionnaires, and documentation. Observation was conducted to identify the conditions of mathematics learning in the classroom and students' needs for interactive learning media. Questionnaires were administered to media experts, subject-matter expert, and the students.

The material expert validation assessed the appropriateness of the instructional content, the alignment of learning objectives with curriculum requirements, and the accuracy of the mathematical concepts embedded in the media. In contrast, the media expert validation evaluated the presentation quality, interactivity, visual communication, and graphical design of the learning media. Feedback from both experts was utilized to revise and improve the product prior to its implementation in the classroom (Agusta, 2025).

Student responses were measured using a practicality questionnaire to determine the usability and acceptance of the developed learning media. The assessed indicators included the attractiveness of the media display, the ease of understanding the material through the use of text, colors, and images, the clarity

of language, students' enthusiasm during learning activities, the usefulness of the media in facilitating conceptual understanding, and its ability to encourage students to engage more actively in learning. These indicators were used to evaluate the practicality and user-friendliness of the developed media from the students' perspective (Agusta, 2025).

Documentation was employed to collect supporting data, including photographs of learning activities, expert validation results, product revision sheets, screenshots of the developed GeoGebra media, and records of the media implementation process. These documentation data served to strengthen the research findings, verify the media development process, and support the interpretation of the product's validity and practicality results.

The research instruments were first subjected to content validity testing through expert judgment to ensure that the indicators were aligned with the research objectives. In addition, instrument reliability was analyzed to determine the consistency of the measurement results, thereby ensuring that the instruments were appropriate for use in the study. The assessment indicators for media experts

and subject matter experts are presented in Table 1.

Table 1. Media and Material Validation Indicators

Assessment Aspect	Indicator
Material Expert Validation	Alignment of the content with the intended learning outcomes
	Clarity and appropriateness of the learning objectives
	Accuracy of triangle concepts, including definitions, types, perimeter, and area
	Relevance of the learning media content to the instructional material
	Logical organization and systematic presentation of the content
Media Expert Validation	Ability of the media to enhance students' motivation and learning interest
	Level of interactivity provided by the media
	Quality of visual communication, including readability, layout, and animation
	Systematic presentation of learning components
	Quality of graphical design, including layout, color selection, background, images, and animations
Student Responses	Attractiveness of the learning media
	Ease of understanding the material through text, colors, and images
	Clarity of language used in the media
	Students' enthusiasm when using the media
	Usefulness of the media in facilitating understanding of the learning material
	Ability of the media to encourage more active learning engagement

The data obtained from the validation process and student responses were analyzed using the following percentage formula:

$$NP = \frac{R}{SM} \times 100\%$$

Where:

NP = Percentage score obtained

R = Total Score achieved
SM = Maximum possible score

The results of the analysis were subsequntly categorized based of the criteria of media validity and practicality, as presented in Table 2.

Table 2. Creteria for Validity, Practicality, and Student Response Categories

Interval	Category
81-100%	Very Valid
61-80%	Valid
41-60%	Fairly Valid
21-40%	Less Valid
0-20%	Invalid

C. Results dan Discussion

The development of the GeoGebra-based learning media for triangle concepts was carried out using the ADDIE model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation**.** Based on the needs analysis, it was found that elementary school students still experienced difficulties in understanding plane geometry concepts, particularly triangle concepts, because these concepts were abstract and the learning process tended to be conventional. This condition resulted in limited conceptual understanding and low student engagement during mathematics learning activities. Therefore, a GeoGebra-based learning medium integrated with a Deep Learning approach was developed to create a more interactive, contextual, and student-centered learning environment. The developed learning media were designed to facilitate students' exploration of triangle concepts through the direct manipulation of geometric objects, enabling abstract concepts to become more concrete and meaningful.

During the development stage, the learning media were designed using Canva to support the presentation of instructional materials and GeoGebra as an interactive platform for exploring triangle concepts. The developed product was subsequently validated by a media expert and a subject-matter expert to evaluate its feasibility prior to classroom implementation. The validation process generated several recommendations for improvement, particularly regarding the alignment of the instructional content with the learning objectives, the clarity of concept presentation, and enhancements to the visual design to improve its attractiveness and suitability for elementary school students. Figure 1 presents the initial version of the learning media before expert validation and revision.

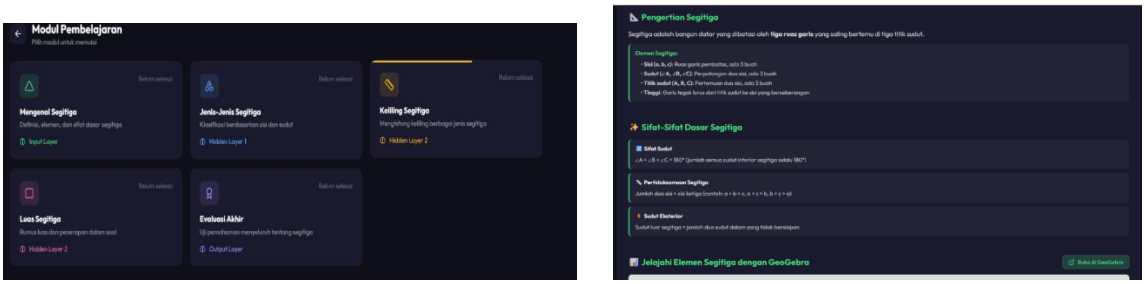


Figure 1. Media Before Revision

Following revisions based on the experts' recommendations, the learning media achieved a validation score of 88% for the media aspect and 83% for the content aspect, both of which were classified as highly valid. These findings indicate that the developed learning media met the established feasibility criteria, including content alignment with the instructional objectives, visual design quality, interactivity, and the relevance of the instructional materials to mathematics learning outcomes at the elementary school level. The high validation scores suggest that the develop learning media were suitable for supporting mathematics instruction on triangle concepts. Furthermore, the validation process served not only to means of evaluate the quality of the product but also to guide its refinement through revisions based on experts' recommendations. These revisions included improving the instructional content, enhancing the clarity of concept presentation, optimizing the visual design, and refining the interactive features to ensure that the learning media were more engaging, user-friendly, and aligned with the characteristics and learning needs of elementary school students. Figure 2 until figure 7 illustrates the final version of the developed learning media following the revisions made in accordance with the recommendations provided by the expert validators.

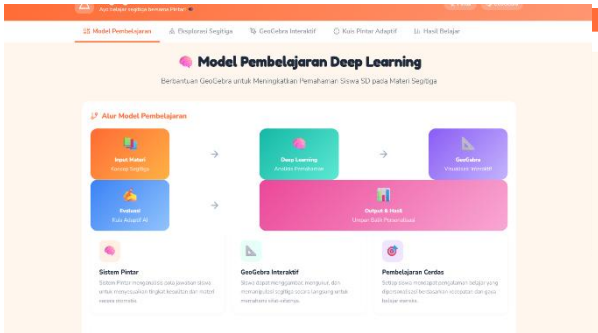


Figure 2. Cover

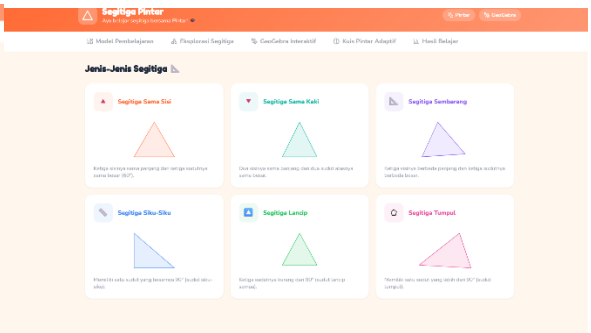


Figure 3. Material

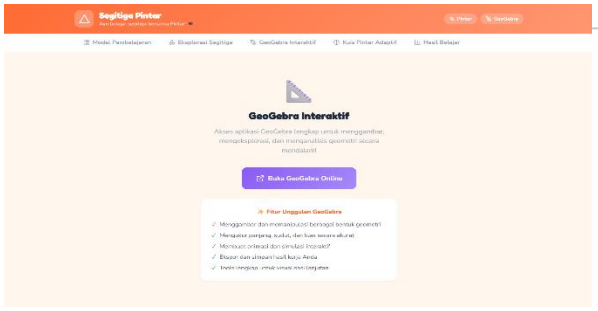


Figure 4. Interactive GeoGebra Link

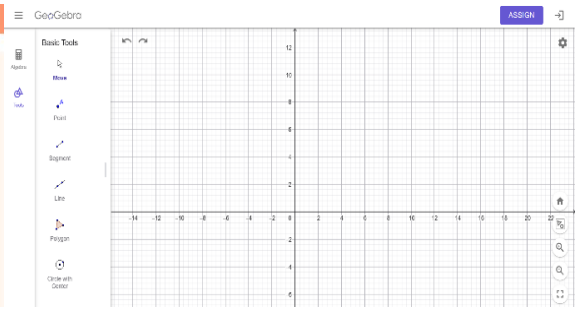


Figure 5. GeoGebra Initial View

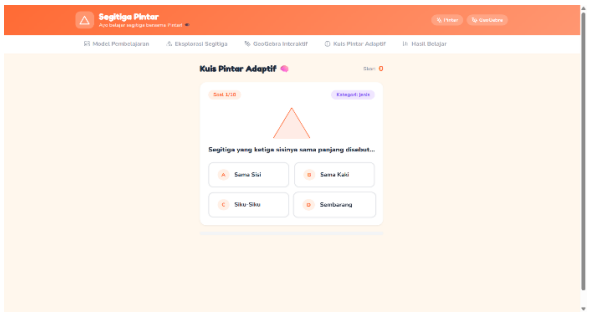


Figure 6. Student Interactive Quiz

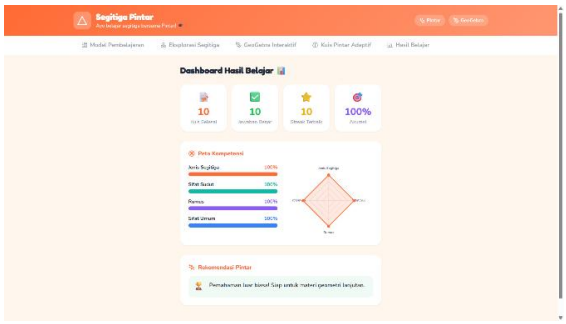


Figure 7. Learning Outcomes Dashboard

The implementation stage involved 21 fifth-grade elementary school students who had previously studied triangle concepts. The trial results revealed that students' responses to the GeoGebra-based Triangle Deep Learning media reached 91%, which was categorized as "very practical." This high level of student response indicates that the developed learning media were perceived as attractive, easy to use, and effective in enhancing student engagement during the learning process. Furthermore, the use of dynamic visualizations and exploratory activities within the media helped students understand the relationships among the sides, angles, perimeter, and area of triangles more clearly and systematically. Therefore, the developed learning media were considered feasible for supporting mathematics learning, particularly the teaching of triangle concepts at the elementary school level.

Nevertheless, the implementation process encountered several technical and pedagogical challenges. These challenges included the limited availability of supporting devices, such as computers or laptops, differences in students' initial abilities to operate digital media, and unstable internet connectivity, which affected the smooth implementation of the learning media. Moreover, during the initial stage of implementation, students still required guidance and assistance from teachers to operate the GeoGebra features effectively. Despite these limitations, the identified challenges did not diminish students' enthusiasm during the learning process. Instead, they provided valuable considerations for improving and optimizing the learning media in future studies. Formative evaluation was

conducted through expert validation and practicality testing of the developed media. However, a summative evaluation aimed at determining the effectiveness of the media in improving students' learning outcomes was not conducted, as the primary focus of this study was product development and feasibility assessment. Therefore, further research is recommended to examine the effectiveness of the developed learning media using a more comprehensive experimental research design.

The findings of this study indicate that the GeoGebra-based Deep Learning media developed using the ADDIE model achieved a very high level of validity and practicality for elementary mathematics learning. The high validation results obtained from both the media expert and the subject-matter expert indicate that the developed media met the criteria for content feasibility, alignment with instructional objectives, interactivity, visual presentation, and ease of use in accordance with the characteristics of elementary school students. The validity of the learning media was influenced not only by the quality of Geo Gebra's visualizations as an interactive learning platform but also by the integration of the Deep Learning approach, which was designed to promote in-depth conceptual exploration through the direct manipulation of geometric objects. This integration enabled students not only to receive information passively but also to construct conceptual understanding through active, contextual, and reflective learning experiences. These findings are consistent with those reported by (Prasetya et al., 2024), who found that the use of Geo Gebra enhanced students' spatial reasoning skills through interactive exploratory activities. Accordingly, the developed learning media facilitated the transformation of abstract geometric concepts into more concrete representations, making them easier for elementary school students to understand.

The high level of media practicality indicates that the developed learning media were capable of providing an engaging and user-friendly learning experience for students. This practicality was supported by the use of dynamic visualizations, real-time object manipulation features, interactive quizzes, and the systematic presentation of instructional materials aligned with the cognitive development level of elementary school students. The use of GeoGebra enabled students to directly observe changes in the relationships among the sides, angles, perimeter, and area of triangles, thereby making the learning process more exploratory and meaningful. These findings suggest that the developed learning media functioned not only as a visualization tool but also as a learning environment that encouraged students' active engagement in constructing knowledge independently. These findings are consistent with those reported by (Hidayati et al., 2022), who found that GeoGebra-based learning media were highly practical and capable of facilitating engaging learning experiences through dynamic visualizations and interactive features. Such

findings are also consistent with constructivist learning theory, which emphasizes direct learning experiences and encourages students to construct knowledge independently.

The Deep Learning approach was integrated into the GeoGebra-based learning media through exploratory, reflective, and interactive activities that facilitated students' meaningful construction of triangle concepts. Dynamic visualizations and the direct manipulation of geometric objects promoted *meaningful learning*, whereas analytical and reflective tasks supported *mindful learning*. In addition, the media's interactive features fostered *joyful learning* by increasing students' engagement and participation throughout the learning process. Consequently, the developed learning media functioned not only as a visualization tool but also as a pedagogical medium that supported deeper conceptual understanding and student-centered learning.

From a theoretical perspective, this study supports the view that integrating interactive technology with a Deep Learning approach can enhance the quality of mathematics learning in elementary schools. The Deep Learning approach implemented within the learning media provided opportunities for students to engage more actively in conceptual exploration, reflection, and problem-solving than in conventional teacher-centered instruction. Furthermore, the use of GeoGebra in geometry learning supports visual-spatial learning theory by enabling students to learn through visual representations and the direct manipulation of geometric objects. (Hutasoit et al., 2025) reported that integrating interactive technologies such as GeoGebra can improve mathematics learning by facilitating deeper exploration, reflection, and problem-solving processes. This finding is consistent with visual-spatial learning theory, which emphasizes that students understand concepts more effectively through direct interaction and object manipulation than through traditional instructional methods. Therefore, the developed learning media have the potential not only to improve students' conceptual understanding of mathematics but also to support the development of critical thinking, creativity, collaboration, and independent learning skills, which are essential competencies for 21st-century education.

Nevertheless, this study has several limitations. The media development process was conducted only up to the implementation stage; therefore, the effectiveness of the developed media in improving students' learning outcomes has not yet been comprehensively examined through an experimental research design. In addition, the implementation process encountered several challenges, including the limited availability of supporting devices, unstable internet connectivity, and differences in students' initial abilities to operate digital media. These findings indicate that the successful implementation of technology-based learning media is influenced not only by the quality of the media itself but also by the readiness of

infrastructure and users' digital competencies. This finding is consistent with that of (Pradana & Josiah, 2024), who emphasized that internet connectivity and the availability of digital devices are essential factors supporting the effectiveness of technology-based learning media. Limited internet access, particularly in areas with inadequate infrastructure, may hinder the implementation of digital learning activities. Moreover, insufficient digital devices may reduce students' opportunities to interact optimally with the learning media, potentially affecting student participation and learning effectiveness. Therefore, future studies are recommended to examine the effectiveness of the developed media using pretest–posttest experimental designs, involve broader research participants, and develop more adaptive and flexible learning media that can be accessed across various devices and learning environments.

From a pedagogical perspective, this study contributes to the development of mathematics learning that is more active, interactive, and student-centered. The GeoGebra-based Deep Learning media assist teachers in creating more contextual geometry learning experiences through direct visualization and conceptual exploration activities. In addition, the developed media have broad implementation potential because they can be applied not only to triangle concepts but also to other geometry topics, such as quadrilaterals, geometric transformations, and three-dimensional shapes. (Aisyah & Setyawan, 2025) reported that GeoGebra can be adapted to various instructional materials, making it a valuable tool for educators seeking to enhance students' understanding of geometry concepts. Therefore, the development of GeoGebra-based learning media using the ADDIE model may serve as an innovative alternative for supporting more effective, meaningful, and 21st-century-oriented mathematics learning in elementary schools.

D. Conclucion

Based on the findings of this study, the development of GeoGebra-based learning media for triangle concepts using the ADDIE approach made a meaningful contribution to mathematics learning in elementary schools. The developed learning media presented triangle concepts in a visual, dynamic, and interactive manner through exploratory activities and the manipulation of geometric objects, enabling students to understand abstract concepts more concretely and meaningfully. The validation results showed that the media expert assessment reached 88%, the subject-matter expert assessment reached 83%, and student responses reached 91%, indicating that the developed learning media were highly valid and highly practical for use in elementary mathematics learning.

From a pedagogical perspective, the use of the GeoGebra-based learning media contributed to creating a more active, interactive, and student-centered mathematics learning environment through the concrete visualization of geometric

concepts. Furthermore, the developed media have the potential to be adapted for various geometry topics according to students' characteristics and instructional needs. Nevertheless, this study has several limitations. Although the developed learning media were implemented in classroom instruction, the scope of the study was limited to product development, validation, and practicality testing. Consequently, the effectiveness of the learning media in improving students' learning outcomes was not examined through a comprehensive experimental design. In addition, the implementation involved a relatively small sample and was conducted in a single school. Therefore, future studies are recommended to investigate the effectiveness of the developed learning media using experimental research designs, involving larger and more diverse participant groups and examining their impact on various aspects of mathematics learning.

E. Acknowledgments

The researcher would like to express sincere gratitude to the school where the study was conducted for the facilities, support, time, and cooperation provided throughout the research process.

F. Author Contributions Statement

SB was responsible for the conceptualization of the study, needs analysis, instructional media design and development, data collection, data analysis, product revision, manuscript preparation, and writing of the original draft. UAW and ENR contributed through academic supervision, methodological guidance, validation of the research design, critical review, and manuscript revision.

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